

DERWENT-ACC-NO: 2003-363377  
DERWENT-WEEK: 200828  
COPYRIGHT 2008 DERWENT INFORMATION LTD

TITLE: Steel sheet for container contains specified mass ratio of carbon, nitrogen, and boron, and has specified proportions of aluminum nitride and boron nitride

INVENTOR: MURAKAMI H; TANAKA S ; TORISU K

PRIORITY-DATA: 2001JP-341515 (November 7, 2001), 2001JP-308284 (October 4, 2001)

PATENT-FAMILY:

PUB-NO	PUB-DATE	LANGUAGE
<u>WO 03031670</u>	April 17, 2003	EN
<u>A1</u>		
<u>KR 2004037255</u>	May 4, 2004	KO
<u>A</u>		
<u>JP 2005504891</u>	February 17, 2005	JA
<u>W</u>		
<u>CN 1599804</u>	March 23, 2005	ZH
<u>A</u>		
<u>KR 627430</u>	September 25, 2006	KO
<u>B1</u>		
<u>CN 1873038</u>	December 6, 2006	ZH
<u>A</u>		
<u>CN 100336930</u>	September 12, 2007	ZH
<u>C</u>		

INT-CL-CURRENT:

TYPE	IPC	DATE
CIPS <u>C21 D 8/02</u>		20060101
CIPP <u>C21 D 9/46</u>		20060101
CIPS <u>C22 C 38/00</u>		20060101
CIPP <u>C22 C 38/00</u>		20060101
CIPS <u>C22 C 38/04</u>		20060101
CIPS <u>C22 C 38/06</u>		20060101
CIPP <u>C22 C 38/06</u>		20060101
CIPP <u>C22 C 38/06</u>		20060101
CIPS <u>C22 C 38/16</u>		20060101
CIPS <u>C22 C 38/60</u>		20060101

ABSTRACTED-PUB-NO: WO 03031670 A1  
BASIC-ABSTRACT:

**NOVELTY** - Steel sheet for a container contains at most 0.005 mass% carbon, at most 0.006 mass% nitrogen, and boron so that the ratio of boron/nitrogen may be 0.4-2; and has aluminum nitride and boron nitride in the steel, where the ratio of nitrogen existing as aluminum nitride to nitrogen existing as boron nitride is at most 0.4.

**DESCRIPTION** - An **INDEPENDENT CLAIM** is also included for a method of producing a steel sheet for a container, which comprises controlling the reheating temperature of a slab to at least 1100 degreesC or the coiling temperature to at most 730 degreesC in hot-rolling, or controlling the annealing temperature after cold-rolling to at most 700 degreesC, when the steel sheet for a container is produced in the ordinary production processes using a steel containing the above composition.

**USE** - The steel sheet is used as a material for a container, i.e. a three-piece can useful in the field of the production of beverage cans or food cans.

**ADVANTAGE** - The steel sheet provides a material for a container, which is excellent in formability and fatigue property at a weld, without the deterioration of the strip threading performance during annealing. It improves the formability of the weld during can manufacturing and reduces cracking at the weld.

**DESCRIPTION OF DRAWING(S)** - The figure is a view showing the method of evaluating the workability of a weld.

ABSTRACTED-PUB-NO: WO 03031670 A1  
EQUIVALENT-ABSTRACTS:

#### METALLURGY

**Preferred Composition:** The steel sheet further contains at most 0.04 mass% aluminum and/or 0.001-0.007 mass% oxygen. It may further contain 0.015-2 mass% silicon, 0.05-2 mass% manganese, and 0.005-0.08 mass% phosphorus. It further contains at most 0.01 mass% titanium and at most 0.01 mass% niobium. The sulfides contained in the steel satisfy the expression, where (sulfur existing as copper sulfides)/(sulfur existing as manganese sulfides) is at most 0.1. The steel sheet may contain 0.0005-0.04 mass% carbon, 0.002-0.5 mass% silicon, 0.03-2 mass% manganese, 0.002-0.08 mass% phosphorus, 0.01-0.06 mass% sulfur, 0.001-0.07 mass% aluminum, and 0.002-0.03 mass% nitrogen, where the content of nitrogen dissolved in the steel is 20-300 ppm, and the balance consists of iron and impurities.

**Preferred Method:** The steel sheet is subjected to a secondary cold-rolling under the reduction ratio of at most 20% after the processes of continuous casting of molten steel, hot rolling, pickling, cold-rolling, and annealing. The method includes commencing hot-rolling under the condition that the heat history in 1000-1300 degreesC after producing a slab by continuously casting molten steel and before commencing the hot-rolling satisfies the expression, where temperature in degreesC x time in minutes is at most 200000. It further includes controlling the average cooling rate in the period from the commencement of the finish hot-rolling to the coiling after the completion of the finish hot-rolling

to at most 30 degreesC/second.

CHOSEN-DRAWING: Dwg.1/5

## CORRECTED VERSION

(19) World Intellectual Property  
Organization  
International Bureau



(43) International Publication Date  
17 April 2003 (17.04.2003)

PCT

(10) International Publication Number  
WO 2003/031670 A1

(51) International Patent Classification?: C22C 38/06

(21) International Application Number:  
PCT/JP2002/010387

(22) International Filing Date: 4 October 2002 (04.10.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
2001-308284 4 October 2001 (04.10.2001) JP  
2001-341515 7 November 2001 (07.11.2001) JP

(71) Applicant: NIPPON STEEL CORPORATION [JP/JP];  
6-3, Otemachi 2 chome, Chiyoda-ku, Tokyo 100-8071  
(JP).

(72) Inventors: MURAKAMI, Hidekuni; C/O NIPPON  
STEEL CORPORATION YAWATA WORKS, 1-1, Tobi-  
hata-cho, Tobata-ku, Kitakyushu-shi, Fukuoka 804-8501  
(JP). TANAKA, Seichiro; C/O NIPPON STEEL COR-  
PORATION YAWATA WORKS, 1-1, Tobihata-cho,  
Tobata-ku, Kitakyushu-shi, Fukuoka 804-8501 (JP).

TORISU, Kelihiro; C/O NIPPON STEEL CORPORA-  
TION YAWATA WORKS, 1-1, Tobihata-cho, Tobata-ku,  
Kitakyushu-shi, Fukuoka 804-8501 (JP).

(74) Agents: ISHIDA, Takashi et al.; A. AOKI, ISHIDA &  
ASSOCIATES, Toranomon 37 Mori Bldg., 5-1, Toranomon  
3-chome, Minato-ku, Tokyo 105-8423 (JP).

(81) Designated States (national): CN, JP, KR, MX, PH.

(84) Designated States (regional): European patent (AT, BE,  
CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC,  
NL, PT, SE, TR).

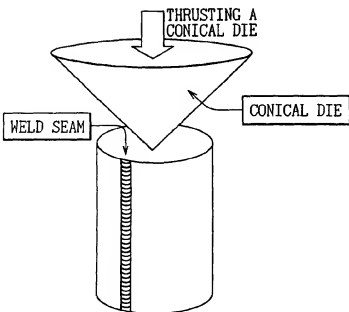
Published:  
— with international search report

(48) Date of publication of this corrected version:  
4 March 2004

(15) Information about Correction:  
see PCT Gazette No. 10/2004 of 4 March 2004, Section II

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: STEEL SHEET FOR CONTAINER AND METHOD OF PRODUCING THE SAME



(57) Abstract: The present invention is an invention having the object of providing a steel sheet for a container having a weld, which can prevent the decline of productivity caused by buckling at the process of annealing the steel sheet, the occurrence of cracks at a weld during can manufacturing, and the occurrence of cracks at a weld during the use of a can. The first present invention is characterized by: containing, in mass, C: 0.0050% or less and N: 0.0060% or less; controlling the ratio B/N within the range from 0.4 to 2.0; satisfying the expression,  $(N \text{ existing as } ALN)/(N \text{ existing as } BN) \leq 0.4$ ; and, as occasion demands, controlling the ratio A/B to 30 or less; controlling the reheating temperature of a slab at hot rolling to 1,100 degree Celsius or higher. The second present invention is a steel sheet for a container, excellent in formability and fatigue property at a weld, characterized by: containing, in mass, C: 0.0005 to 0.040%, Si: 0.002 to 0.50%, Mn: 0.03 to 2.00%, P: 0.002 to 0.080%, S: 0.0100 to 0.0600%, Al:

0.0010 to 0.0700%, and N: 0.0020 to 0.0300%, the content of solute N being 20 to 300 ppm.

WO 2003/031670 A1



---

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

## DESCRIPTION

STEEL SHEET FOR CONTAINER  
AND METHOD OF PRODUCING THE SAME

5

## Technical Field

10 The present invention relates to a steel sheet, used  
of producing the steel sheet, as represented by the  
production of a three-piece can. That is, the present  
invention provides an ultra-thin material, for a  
15 container, which can be produced with a high productivity  
and is excellent in formability at a weld, in the fields  
of the production of steel sheets and the production of  
cans.

## Background Art

20 A container, as a can drum formed by welding and  
called a three-piece can, is used in the field of the  
production of beverage cans, food cans and the like.  
Flange forming is applied to a can drum for expanding the  
openings thereof so that a can bottom and a can top may  
25 be attached to the can drum and, in this case, it is  
required for the weld to have an excellent formability.  
In addition, in case of a large container or the like,  
welding is often adopted when a metal handle is attached  
to the container and sometimes the strength, particularly  
30 the fatigue strength, at a weld is a problem.

In the meantime, the thickness of a steel sheet for  
a container has become thinner, from the viewpoint of  
cost reduction, and this leads to the deterioration of  
the ductility and fatigue property of the steel sheet.  
35 Therefore, a good formability and a high strength at a  
weld are also required of an ultra-thin steel sheet.  
Further, an ultra-thin steel sheet that has been cold-

rolled to the thickness of the end product is apt to generate buckling, called a heat-buckle, during continuous annealing, and that causes a very poor strip threading performance and a marked deterioration of productivity.

To solve the above problems, Japanese Unexamined Patent Publication Nos. H3-257123 and H2-118026 and other publications disclose a DR material produced by the so-called DR method (double reduced method), wherein a steel sheet having a thickness thicker than the final product is processed during annealing and, after the annealing, the thickness of the final product is obtained by secondary cold-rolling. However, in the steel sheet hardened by the secondary cold-rolling, the softening of the material at a weld is caused by the recovery and recrystallization of the material due to the heat generated during welding and, thus, the stress concentration in the vicinity of the weld is increased and the formability and fatigue property are deteriorated.

Further, Japanese Unexamined Patent Publication No. H10-72640 discloses a method of securing the strength of a steel sheet by increasing solute N, but, by this method, the stress concentration at a weld is excessive and thus the formability and fatigue strength of the weld are not improved sufficiently.

Yet further, Japanese Unexamined Patent Publication No. H2-118028 discloses a method of improving flange formability by decreasing solute C and N or by improving the Lankford value. Further, Japanese Unexamined Patent Publication No. S63-89625 discloses a technology of improving flange formability by fining grain sizes by the addition of Nb and B. Further, Japanese Unexamined Patent Publication No. S61-34159 discloses a technology of improving flange formability by fining cementite, and Japanese Unexamined Patent Publication No. S63-310922 discloses a technology of improving flange formability by

specifying the conditions of overaging heat treatment.

In the meantime, Japanese Unexamined Patent Publication No. S63-317625 discloses a technology of avoiding the cracking of a weld by adding Ti, Nb and B and thus increasing the strength of the weld, in regard  
5 to the softening of a heat affected zone by welding as the cause of the cracking when a steel sheet for automobile use is subjected to spot welding. However, in case of an ultra-thin material, cracking of a base  
10 material becomes conspicuous when the strength of a weld is excessive, and the flange formability is rather deteriorated.

As mentioned above, the mechanism of the improvement of flange formability has not been clarified yet, and  
15 thus various measures for the improvement have been taken, but measures do not take the threading performance of an ultra-thin material in an annealing furnace into consideration and a mere addition of Ti, Nb and B makes the recrystallization temperature of a steel sheet high  
20 and makes it necessary to raise the annealing temperature and, thus, the strip threading performance in an annealing furnace is markedly deteriorated.

#### Disclosure of the Invention

25 The present invention, which has been established in view of the above-mentioned situation, provides a steel sheet for a container. The present invention makes it possible to produce an ultra-thin material used for a container having a weld with a high productivity but  
30 without the deterioration of the strip threading performance during annealing, to improve the formability of the weld during can manufacturing, and to reduce cracking at the weld which is a problem when it is used.

35 The present invention is a method of improving flange formability at a weld during can forming and fatigue strength at the weld during use by appropriately preparing a base material so that the material quality of



the weld, which is apt to generate a stress concentration during forming or use, may be suitable for the object. That is, the present invention is a method, for a B added ultra-low carbon steel, of further improving the properties by regulating the form of nitrides within an appropriate range and adding elements in very small amounts.

More specifically, the present invention is a steel sheet for a container, excellent in formability and fatigue property at a weld, and a method of producing the steel sheet. The present invention is composed of the following items:

(1) A steel sheet for a container, excellent in formability and fatigue property at a weld, characterized by: containing, in mass,  
C: 0.0050% or less,  
N: 0.0060% or less, and  
B so that the ratio B/N may be within the range from 0.40 to 2.00; and  
having AlN and BN in the steel satisfy the expression,  
$$(N \text{ existing as AlN}) / (N \text{ existing as BN}) \leq 0.40.$$

(2) A steel sheet for a container, excellent in formability and fatigue property at a weld, according to the item (1), characterized by: further containing, in mass,  
Al: 0.040% or less; and  
the ratio Al/B being 30 or less.

(3) A steel sheet for a container, excellent in formability and fatigue property at a weld, according to the item (1) or (2), characterized by further containing, in mass,  
O: 0.0010 to 0.0070%.

(4) A steel sheet for a container, excellent in formability and fatigue property at a weld, according to

any one of the items (1) to (3), characterized by further containing, in mass,  
Si: 0.015 to 2.00%,  
Mn: 0.05 to 2.00%, and  
5 P: 0.005 to 0.080%.

(5) A steel sheet for a container, excellent in formability and fatigue property at a weld, according to any one of the items (1) to (4), characterized by further  
10 containing, in mass,  
Ti: 0.010% or less and  
Nb: 0.010% or less.

(6) A steel sheet for a container according to any one of the items (1) to (5), characterized in that the sulfides contained in the steel satisfy the expression,  
15  $(S \text{ existing as Cu sulfides}) / (S \text{ existing as Mn sulfides}) \leq 0.10$ .

(7) A method of producing a steel sheet for a container, excellent in formability and fatigue property at a weld, characterized by controlling the reheating temperature of a slab to 1,100°C or higher in hot-rolling when the steel sheet for a container is produced in the  
20 ordinary production processes using a steel containing the components according to any one of the items (1) to  
25 (6).

(8) A method of producing a steel sheet for a container, excellent in formability and fatigue property at a weld, characterized by controlling the coiling temperature to 730°C or lower in hot-rolling when the steel sheet for a container is produced in the ordinary production processes using a steel containing the  
30 components according to any one of the items (1) to (6).  
35

(9) A method of producing a steel sheet for a

container, excellent in formability and fatigue property at a weld, characterized by controlling the annealing temperature after cold-rolling to 700°C or lower when the steel sheet for a container is produced in the ordinary production processes using a steel containing the components according to any one of the items (1) to (6).

(10) A steel sheet for a container, excellent in formability and fatigue property at a weld, characterized by: containing, in mass,  
C: 0.0005 to 0.040%,  
Si: 0.002 to 0.50%,  
Mn: 0.03 to 2.00%,  
P: 0.002 to 0.080%,  
S: 0.0100 to 0.0600%,  
Al: 0.0010 to 0.0700%, and  
N: 0.0020 to 0.0300%;  
the content of N dissolved in the steel sheet being 20 to 300 ppm; and  
the balance consisting of Fe and unavoidable impurities.

(11) A steel sheet for a container, excellent in formability and fatigue property at a weld, according to the item (10), characterized by further containing, in mass, one or more of,  
Nb: 0.0005 to 0.0050%,  
Ti: 0.0005 to 0.0050%, and  
B: 0.0010% or less.

(12) A steel sheet for a container, excellent in formability and fatigue property at a weld, according to the item (10) or (11), characterized by further containing, in mass,  
O: 0.0015 to 0.0090%.

(13) A steel sheet for a container, excellent in formability and fatigue property at a weld, according to

- any one of the items (10) to (12), characterized by further containing, in mass, one or more of,  
Cu: 0.0005 to 0.050%,  
Ni: 0.0005 to 0.100%, and  
5 Cr: 0.0005 to 0.100%.

- (14) A steel sheet for a container, excellent in formability and fatigue property at a weld, according to any one of the items (10) to (13), characterized by  
10 further containing, in mass,  
Sn: 0.0002 to 0.0050%.

- (15) A steel sheet for a container, excellent in formability and fatigue property at a weld, according to  
15 any one of the items (1) to (14), characterized in that the sulfides contained in the steel satisfy the expression,  
(S existing as Cu sulfides)/(S existing as Mn sulfides) < 0.30.

- 20 (16) A method of producing a steel sheet for a container, excellent in formability and fatigue property at a weld, according to any one of the items (10) to (15), characterized in that the steel sheet is subjected  
25 to a secondary cold-rolling under the reduction ratio of 20% or less after the processes of continuous casting of molten steel, hot-rolling, pickling, cold-rolling and annealing.

- 30 (17) A method of producing a steel sheet for a container, excellent in formability and fatigue property at a weld, according to any one of the items (1) to (16), characterized by commencing hot-rolling under the condition that the heat history in the temperature range  
35 from 1,000 to 1,300°C after producing a slab by continuously casting molten steel and before commencing the hot-rolling satisfies the expression,

temperature ( $^{\circ}\text{C}$ )  $\times$  time (min.)  $\leq 200,000$ .

(18) A method of producing a steel sheet for a container, excellent in formability and fatigue property at a weld, according to any one of the items (1) to (17), characterized by hot-rolling the steel sheet by controlling the average cooling rate, in the period of time from the commencement of the finish hot-rolling to the coiling after the completion of the finish hot-rolling, to  $30^{\circ}\text{C}/\text{sec.}$  or less.

#### Brief Description of the Drawings

Figure 1 is a view showing the method of evaluating the workability of a weld.

Figure 2 is a view showing the method of evaluating a weld by a tensile test.

Figure 3 is a view showing the method of evaluating the fatigue strength of a weld.

Figure 4 is a graph showing the relation between (N existing as ALN)/(N existing as BN) and workability.

Figure 5 is a graph showing the relation between (N existing as ALN)/(N existing as BN) and fatigue strength.

#### Best Mode for Carrying out the Invention

##### Embodiment 1

The present invention according to claims 1 to 9 will hereunder be explained in detail.

Firstly, chemical components will be explained hereunder. In the explanation, the amount of each chemical component is expressed in terms of mass %.

C content is generally preferred to be as low as possible from the viewpoint of workability, and therefore the upper limit thereof is set at 0.0050%. In particular, when a good ductility with a low aging property is required, the property can be improved remarkably by reducing C content down to 0.0015% or less. However, because an excessive reduction of C content

causes not only a cost to increase but also a steel sheet to soften and hence the strength of a can to deteriorate, the lower limit is preferred to be 0.0030%.

5 N is an important element to control the formation of nitrides, which is an important requirement of the present invention. Because an excessive content of N causes excessive formation of nitrides and hence the object of the present invention cannot be achieved, the upper limit thereof is set at 0.0060%. When the addition  
10 amount of B is comparatively small, as will be explained later, a problem with an aging property caused by the residue of solute N may arise, and therefore it is preferable to control N content to 0.0030% or less in order to reduce the aging effect. Further, if the N  
15 content is controlled to 0.0020% or less by applying a vacuum degassing treatment sufficiently, the formation of nitrides is suppressed and, in particular, formability is improved.

B is added as an indispensable element in the preset  
20 invention, because B affects the form of nitrides, changes material properties at the heat affected zone of a weld, lowers the recrystallization temperature of a steel sheet when it is added properly, hence makes it possible to anneal a steel sheet at a lower temperature,  
25 and, as a result, improves the strip threading performance during annealing. However, an excessive addition of B causes a weld to harden excessively, thus workability to deteriorate, a recrystallization temperature to rise necessitating a rise in an annealing  
30 temperature, and, as a result, heat-buckling to occur easily. An important point is the ratio of B to N, and the ratio B/N is set at 0.40 to 2.00, preferably 0.60 to 1.40.

35 An important requirement in the present invention is to control the kind and amount of nitrides, and the ratio of the N amount existing as AlN to the N amount existing as BN in a boron added ultra-low carbon steel must be

0.40 or less, preferably 0.20 or less.

Here, the N amount existing as AlN is a value obtained by analyzing Al amount in a residue when a steel sheet is dissolved in an iodine alcohol solution and then  
5 calculating the N amount regarding the whole Al amount as a constituent of AlN. Likewise, the N amount existing as BN is a value obtained by analyzing the B amount in a residue when a steel sheet is dissolved in an iodine alcohol solution and then calculating N amount regarding  
10 the whole B amount as a constituent of BN.

As mentioned above, in order to control nitrides, the addition amounts of Al and B, the ratio between them, the oxides which act as the precipitation nuclei of nitrides, namely the O content in a steel, and heat  
15 history throughout the all production processes are important factors. By controlling Al/B to 30 or less, preferably 20 or less, and Al to 0.040% or less, preferably 0.020% or less, solute N existing excessively in a steel combines with B more preferentially than Al  
20 when nitrides precipitate, and, by so doing, the kind and amount of nitrides can be controlled desirably.

O is effective for controlling nitrides when the content is within the range from 0.0010 to 0.0070%. The reason is thought to be that O in a steel exists as  
25 oxides containing Si, Al, Mn, and Fe and further microelements such as Ca, Mg, etc., acts effectively as the precipitation nuclei of nitrides when the existing O amount is appropriate, and thus makes a desirable control of nitrides possible. However, an excessive amount of O  
30 in a steel coarsens oxides, acts as the origin of cracks during working, and hence markedly deteriorates the product quality. Therefore, the upper limit of O content is set at 0.0070%.

In order to desirably control the form of oxides as  
35 mentioned above or to improve workability and fatigue strength by adjusting the strength of a base steel sheet and thus mitigating stress concentration in the vicinity

of a weld, Si, Mn, P, etc. can be added. The addition amounts are set at Si: 0.015 to 2.00%, Mn: 0.05 to 2.00% and P: 0.005 to 0.080%, respectively. When the addition amounts miss the ranges, the form of oxides changes, or a weld softens or hardens unusually and, therefore, desired properties cannot be obtained.

The provisions of the upper limits of Ti and Nb, which are added for improving drawability when draw-forming or the like is involved or unavoidably contained in a steel by coming from scraps, etc. during a steelmaking process, are also important requirements in the present invention. Therefore, the content of each element is set at 0.010% or less. When each content exceeds the upper limit, the recrystallization temperature of a steel sheet rises, the strip threading performance in an annealing process markedly deteriorates, a crystal structure coarsens and softens extraordinarily by the influence of heat in the vicinity of a weld, the stress concentration is accelerated at the portion, and, as a result, formability and fatigue strength sometimes deteriorate.

Further, with regard to sulfides in a steel, suppressing the formation of Cu sulfides is also important. In general, S in a steel must be fixed as sulfides in relation to the hot-rolling performance and therefore it is preferable to fix S as MnS in the present invention.

In the present invention, the ratio of (S existing as Cu sulfides) to (S existing as MnS) is set at 0.10 or less. The reason is that the fine precipitation of Cu sulfides causes not only a recrystallization temperature of a steel sheet to rise but also complex-precipitates with B and Al nitrides to form and thus the form of nitrides to be undesirable.

Here, (S existing as Cu sulfides) is a value obtained by quantitatively measuring the Cu amount in a residue obtained by the electrolytic extraction of a



steel sheet and then converting the Cu amount into S amount using the expression,  $Cu/S = 2/1$ , and (S existing as Mn sulfides) a value obtained by quantitatively measuring Mn amount in a residue obtained by the electrolytic extraction of a steel sheet and then converting the Mn amount into S amount using the expression,  $Mn/S = 1/1$ .

The production processes in the present invention include hot-rolling, coiling, pickling, cold-rolling, annealing and skin-pass, etc. which are generally employed.

With regard to a heat history in the production processes, the influences of a reheating temperature of a slab, a coiling temperature during hot-rolling and an annealing temperature after cold-rolling are predominant, and, by restricting a reheating temperature of a slab during hot-rolling to  $1,100^{\circ}\text{C}$  or higher, a coiling temperature during hot-rolling to  $730^{\circ}\text{C}$  or lower and an annealing temperature after cold-rolling to  $700^{\circ}\text{C}$  or lower, the workability and fatigue strength of a weld can be further improved. Though the reasons are not clear, it is thought that the forms of nitrides or of precipitates other than nitrides influence the improvement.

By restricting an annealing temperature after cold-rolling to  $700^{\circ}\text{C}$  or lower, the occurrence of heat-buckling is suppressed and thus the strip threading performance in an annealing process is improved, and therefore the industrial significance is considerable.

As mentioned above, though the mechanism of improving workability and fatigue strength at a weld by controlling the form of nitrides has not been clarified, as a phenomenon, the hardness of a material at a weld and at a heat affected zone in the vicinity thereof is properly adjusted and, by so doing, the stress concentration to the portions is mitigated and a desirable hardness can be obtained. At a weld and in the

vicinity thereof, nitrides are dissolved by the temperature rise during welding and the hardness is determined by fine nitrides wherein both solute N and solute B remain without fully dissolved and fine nitrides precipitating again during cooling. Therefore, in order to obtain the desirable and preferable forms of solute N, solute B and nitrides, it is necessary to control in advance the form of nitrides in a steel before welding as specified in the present invention.

In the production of a thin steel sheet for a container, there are some cases where a steel sheet which is subjected to 2CR rolling after annealing for securing the strength of a container and hardened by the work-hardening is used. In such a steel sheet too, the effects of improving workability and fatigue strength at a weld can be obtained by the present invention. Further, in case of adding elements for improving corrosion resistance and other properties too, the effects of the present invention are not lost.

Even when Sn, W, Mo, Ca, Cr, Ni, V, Sb, etc. are contained for improving the properties which are not referred to in the description of the present invention, such as the workability including drawability and secondary workability and the corrosion resistance of a steel sheet, a strip threading performance in each process, and the like, the effects of the present invention are not lost at all. However, when these elements are added excessively, a strip threading performance during annealing worsens because of the rise of a recrystallization temperature, and therefore it is preferable to control each amount of the elements to 0.10% or less and the total amount thereof to 0.50% or less.

A steel sheet according to the present invention is generally used as the substrate of a surface treated steel sheet and, in that case too, the effects of the present invention are not spoiled at all by the surface

treatment. As a surface treatment for a can, a treatment by tin, chromium (tin-free), nickel, zinc, aluminum or the like is adopted. Further, as the substrate of a laminated steel sheet covered by an organic film, which has come to be used recently, a steel sheet according to the present invention can be adopted without spoiling the effects of the present invention.

#### Embodiment 2

10 The present invention according to claims 10 to 16 will hereunder be explained in detail.

Firstly, chemical components will be explained hereunder. In the explanation, the amount of each chemical component is expressed in terms of mass %.

15 C, when the amount exceeds 0.040%, coarsens carbides and acts as the origin of fracture at a site where stress is concentrated in the vicinity of a weld. On the other hand, an excessive reduction of C content causes the cost to increase and hence the lower limit is set at 0.0005%.

20 Si is generally preferred to be as low as possible from the viewpoint of corrosion resistance. However, when a steel sheet is applied to a so-called laminated steel sheet, the surface of which is coated with a resin film, and the demand for which is increasing recently, 25 the Si content is preferred to be high from the viewpoint of suppressing the deterioration of corrosion resistance and suppressing stress concentration at a weld. On the other hand, an excessive reduction of Si makes it difficult to control the form of oxides desirably as it will be mentioned later, and therefore the Si content is 30 set at 0.002 to 0.5%.

Mn has the same effect as Si and the most proper range is determined to be 0.03 to 2.00%, preferably 0.05 to 1.00%.

35 P is preferred to be as low as possible from the viewpoint of corrosion resistance and stress concentration at a weld. However, P is a useful element

for adjusting the strength of a steel sheet at a low cost. The regulation range of P content is set at 0.002 to 0.080%, preferably 0.002 to 0.030%.

5 S forms sulfides by combining with Mn, Cu, Ti, etc. in a steel. S is an indispensable and important element in the present invention for mitigating stress concentration at a weld by having an appropriate amount of sulfides exist in a steel. S content of at least 0.0100% is required for obtaining the effects of the  
10 present invention. However, an excessive amount of S content sometimes coarsens sulfides and acts as the origin of fracture, and therefore the upper limit is set at 0.0600%.

Al, when the amount is too low in relation to the  
15 amount of oxygen, which will be explained later, makes deoxidization at a steelmaking process insufficient. On the other hand, when the amount is excessive, not only is solute N not secured but also fine AlN is formed abundantly and the recrystallization temperature of a  
20 steel sheet rises, and this results in remarkable deterioration of a strip threading performance in an annealing process. Therefore, Al content is determined to be in the range from 0.0010 to 0.0700%.

N is an important element for controlling solute N  
25 which is one of the important requirements in the present invention. N is added by 0.0020% or more because the effects of the present invention become insufficient when the addition amount is low. On the other hand, when N is contained abundantly, Fe nitrides are generated in a  
30 great amount even when Al content is low and they act as the origin of fracture at a weld. Therefore, the upper limit is set at 0.0300%. Here, with regard to a method of adding N, N can be added either by adding N at the stage of molten steel as it is applied to a regular steel  
35 sheet or by adding N at a heat treatment of a steel sheet in an atmosphere containing ammonia, that is, by nitriding.

The amount of solute N is calculated by subtracting the amount of precipitated N, which can be measured by a method of dissolving a steel in a bromine ester solution, from the total N amount in a steel. When a solute N  
5 amount is small, the softening in the vicinity of a weld cannot be suppressed, but in tern, when it is excessive, aging becomes large and ductility deteriorates. Therefore, the amount of solute N is restricted in the range from 20 to 300 ppm.

10 Since Nb, Ti and B form precipitates by combining with N and moreover Ti forms precipitates by combining with S, a trace addition amount of the elements act effectively on controlling the solute N and the form of sulfides and make the effects of the present invention  
15 more conspicuous. On the other hand, when the addition amount is excessive, the solute N and the form of sulfides become undesirable, and therefore, undesirably, not only the effects of the present invention tend to be spoiled but also the recrystallization temperature of a  
20 steel sheet tends to rise and a strip threading performance during annealing tends to deteriorate. The desirable ranges of the elements are as follows; Nb: 0.0005 to 0.0050%, Ti: 0.0005 to 0.0050% and B: 0.0010% or less.

25 O is an important element for properly controlling the form of oxides, which is one of the important factors of the present invention. When the O content is too small, the amount of oxides for suppressing the softening of a material caused by the heat generation of welding is  
30 insufficient and thus a sufficient effect cannot be obtained. On the other hand, when the O content is excessive, the oxides become the origin of fracture during forming. Therefore, when O is added, the range of the content is determined to be from 0.0015 to 0.0090%,  
35 preferably from 0.0030 to 0.0090%.

Though the reason why an oxygen amount produces a remarkable effect in the present invention has not been

determined yet, it is thought that fine oxides suppress grain growth in a high temperature range during welding, the fine oxides themselves do not change their forms with such a temperature rise as is obtained in the vicinity of a weld, and thus the effect of suppressing softening is maintained. Actually, the prescription on the sizes, numbers and densities of the oxides of Fe, Al, Si and Mn becomes important, and as far as the contents of Al, Si, Mn and O are controlled within the ranges specified by the present invention, the forms of the oxides can be controlled desirably and preferable effects can be obtained as long as usual production conditions are adopted.

Cu, Ni and Cr have the functions of improving the corrosion resistance of a steel sheet and also of suppressing the softening of a material during welding, and therefore the elements are added as occasion demands. Since an excessive addition of the elements causes the deterioration of the ductility of a material, it is preferable, when the elements are added, to control them within the following ranges; Cu: 0.0005 to 0.050%, Ni: 0.0005 to 0.10% and Cr: 0.0005 to 0.100%.

Sn is an element which generally segregates at grain boundaries. As Sn has the effects of suppressing the abnormal grain growth caused by heat generation during welding and hence suppressing the softening of a material, the element can be contained in a steel. As an excessive addition of Sn causes ductility to deteriorate, it is preferable, when it is added, to control the element within the range from 0.0002 to 0.0050%.

In a steel sheet according to the present invention, by properly controlling the form of sulfides, the softening of a weld can be suppressed and hence the desirable properties can be obtained. Though the size, number and density, etc. of sulfides can be specified, in the present invention, the sulfides in a steel are regulated by the expression, (S existing as Cu

sulfides)/(S existing as Mn sulfides)  $< 0.30$ . Though the reason of the above-mentioned effect is not clear, it is estimated that, as CuS is inferior to MnS in the stability at a high temperature, CuS dissolves or  
5 coarsens with a temperature rise during welding and the effect of suppressing the softening of a material is apt to be lost.

Here, (S existing as Cu sulfides) is a value obtained by quantitatively measuring Cu amount in a  
10 residue obtained by the electrolytic extraction of a steel sheet and then converting the Cu amount into S amount using the atom ratio, Cu/S = 2/1, and (S existing as Mn sulfides) a value obtained by quantitatively measuring Mn amount in a residue obtained by the  
15 electrolytic extraction of a steel sheet and then converting the Mn amount into S amount using the atomic ratio, Mn/S=1/1.

A method of satisfying the expression, (S existing as Cu sulfides)/(S existing as Mn sulfides)  $< 0.30$ , is  
20 not particularly restricted and, it can be attained, for instance, by specifying the chemical components, notably the ratio between Mn and Cu. Also, it can be attained by controlling hot-rolling conditions, in particular an average cooling rate between the entry of hot-rolling and  
25 the start of coiling (for instance, controlling the cooling rate to 10 to 50°C/sec. or the like), or by a combination thereof.

A steel according to the present invention is produced through the processes of; continuous casting of  
30 molten steel, hot-rolling, pickling, cold-rolling, annealing and, after that, secondary cold-rolling for controlling the shape or the material properties of a steel sheet. Here, in case of a steel sheet which is subjected to a high reduction ratio in the secondary  
35 cold-rolling, namely which is hardened by a work hardening effect, the material properties are easily recovered in the vicinity of a weld by the temperature

rise during welding and the steel sheet tends to soften. Therefore, the reduction ratio is preferred to be 20% or less.

5 Even when W, Mo, Ca, V, Sb, etc. are contained for improving the properties which are not referred to in the description of the present invention, such as the workability including drawability and secondary workability and the corrosion resistance of a steel sheet, a strip threading performance in each process, and  
10 the like, the effects of the present invention are not lost at all.

A steel sheet according to the present invention is generally used as the substrate of a surface treated steel sheet and, in that case too, the effects of the  
15 present invention are not spoiled at all by the surface treatment. As a surface treatment for a can, a treatment by tin, chromium (tin-free), nickel, zinc, aluminum or the like is adopted. Further, as the substrate of a laminated steel sheet covered by an organic film, which  
20 has been used recently, a steel sheet according to the present invention can be adopted without spoiling the effects of the present invention.

The present invention according to claims 17 and 18 will hereunder be explained in detail.

25 A steel according to the present invention is characterized by dispersing the second phase composed of oxides, nitrides, sulfides and the like in a base phase mainly composed of Fe and, in order to obtain the effects of the present invention, their forms must be controlled  
30 properly. For the purpose, it is particularly effective to control the heat history before a hot-rolling process. As an example, it is preferable to carry out a hot-rolling by commencing the hot-rolling under the condition that the heat history in the temperature range from 1,000  
35 to 1,300°C after producing a slab by continuously casting molten steel and before commencing the hot-rolling satisfies the expression, temperature (°C) x time (min.)



≤ 200,000, and by controlling the average cooling rate in the period of time from the commencement of the finish hot-rolling to the coiling after the completion of the finish hot-rolling to 30°C/sec. or less. Though the reason is not clear, it is thought that, when a steel sheet is retained at a high temperature for a long time, sulfides and nitrides coarsen and disperse as the second phase in extremely large size, in particular, making oxides act as their precipitation nuclei, and, by so doing, the effect of suppressing the softening of a steel sheet caused by the influence of the heat during welding decreases. In general, it is not preferable that the cooling rate is excessively high in the temperature range of about 1,000°C or lower after finish hot-rolling. It is thought that this is because, when the cooling rate in the temperature range is high, the sizes of nitrides and sulfides become very fine when formerly dissolved N and S precipitate as nitrides and sulfides, they dissolve even by the heat during the welding of a product sheet, and the effect of suppressing the softening of a material tends to disappear. In particular, when a cooling rate at this stage is high, S is apt to form Cu sulfides, and therefore the stability against the heat during welding is further decreased. Considering the above situations, as a method of controlling sulfides and nitrides into appropriate shapes, it is recommendable that the method of carrying out a hot-rolling by commencing the hot-rolling under the condition that the heat history in the temperature range from 1,000 to 1,300°C after producing a slab by continuously casting molten steel and before commencing the hot-rolling satisfies the expression, temperature (°C) x time (min.) ≤ 200,000, and controls the average cooling rate in the period of time from the commencement of the finish hot-rolling to the coiling after the completion of the finish hot-rolling to 30°C/sec. or less. Here, the method of controlling the

heat history in the temperature range from 1,000 to 1,300°C after producing a slab by continuously casting molten steel and before commencing the hot-rolling so as to satisfy the expression, temperature (°C) x time (min.)

5     $\leq 200,000$ , includes so-called direct rolling (CC-DR), wherein hot-rolling is commenced without soaking a slab in a reheating furnace or the like after casting, and so-called thin slab continuous casting, wherein a hot-rolling process is simplified or eliminated by making the

10    thickness of a cast slab thin.

#### Example 1

The workability of a weld was evaluated, as shown in Figure 1, by welding a quadrangular steel sheet with seam

15    welding and forming it into a cylindrical shape by the bond along a weld seam, as in the case of manufacturing the can drum of a regular three-piece beverage can, expanding an opening by thrusting a conical die into the opening, and calculating the amount of deformation until

20    cracking occurred at the opening end using the following expression;

$$\{(\text{Diameter at crack generation}) - (\text{Initial diameter})\} / (\text{Initial diameter}) \quad (1).$$

The strength of a weld was evaluated, as shown in

25    Figure 2, by welding two quadrangular steel sheets with spot welding at a welding current just lower than the current at which welding burrs occurred, and measuring the maximum load at a tensile test.

The fatigue strength of a weld was evaluated, as

30    shown in Figure 3, by cutting out a strap 20 mm in width having a weld in the center from a welded cylindrical can drum formed as shown in Figure 1, subjecting the strap to a fatigue tensile test by one side oscillation, and measuring the maximum load at which it can withstand 10

35    million cycles.

Heat buckling was judged by whether or not heat buckling occurred when cold-rolled coils having identical

thickness and width were passed through an identical annealing line at the temperature of the recrystallization temperature + 40°C, and the results were expressed by the marks, O: no occurrence, Δ:

5 little occurrence and x: frequent occurrence.

The effects of the present invention were evaluated by synthetically judging the above-mentioned four evaluation items and expressed by the marks, ◎ : excellent (invented steels), O: good (invented steels),  
10 Δ: good in some of the evaluation items (invented steels) and x:ordinary level (comparative steels).

#### Example 1-1

The steels having the chemical components shown in Table 1 were cast into slabs 250 mm in thickness, then hot-rolled sheets 2.0 mm in thickness were produced at the slab reheating temperature of 1,150°C and the coiling temperature of 650°C, and then steel sheets 0.16 mm in thickness were produced through the processes of  
20 pickling, cold-rolling at the reduction ratio of 92%, annealing at 680°C for 1 min., and then skin pass rolling at the reduction ratio of 3%, and the produced steel sheets were evaluated.

As it is clear from Table 2, the steels produced within the ranges specified in the present invention show excellent properties in all the evaluation items such as the workability, the strength and the fatigue strength of the welds and the heat-buckling resistance.

#### 30 Example 1-2

The steels having various amounts of Ti and Nb as shown in Table 3 were evaluated. The production conditions were the same as those of Example 1.

As it is clear from Table 4, the steels produced within the preferable ranges show excellent properties in  
35 all the evaluation items such as the workability, the



700°C.

As it is clear from Figures 4 and 5, the steels produced within the preferable ranges show excellent properties in the workability and the fatigue strength of the welds.

As explained above, by the present invention, it is possible to reduce the bad formability caused by welding and the fracture during the usage of a can having a weld. Further, as a steel according to the present invention has excellent properties even at an annealing temperature lower than an ordinary annealing temperature, the occurrence of heat buckling can be avoided and an ultra-thin material for a container can be produced with a high efficiency.

Table 1

Steel	C	Si	Mn	P	S	Al	N	B	O	B/N	*1	Al/B
a	0.0011	0.028	0.17	0.011	0.007	0.011	0.0016	0.0025	0.0022	1.56	0.07	4.4
b	0.0012	0.012	0.04	0.009	0.012	0.025	0.0025	0.0009	0.0018	0.36	2.1	27.8
c	0.0023	0.022	0.23	0.004	0.008	0.056	0.0023	0.0018	0.0015	0.78	3.1	31.1
d	0.0015	0.013	0.18	0.011	0.008	0.005	0.0026	0.001	0.0075	0.39	0.05	5
e	0.0027	0.068	0.1	0.018	0.008	0.022	0.0025	0.0018	0.0039	0.72	0.28	12.2
f	0.0007	0.15	1.61	0.007	0.055	0.008	0.0013	0.0008	0.0027	0.62	0.18	10
g	0.0048	0.022	0.59	0.023	0.013	0.014	0.0037	0.0048	0.0016	1.3	0.03	2.9

\*1: (N existing as AlN)/(N existing as BN)

Table 2

Steel	*1	*2	Workability (%)	Strength (N)	Fatigue strength (N)	Heat buckling	Judgment
a	25	35	20	167	1127	○	Inventive steel
a1	8	5	22	180	1240	○	Inventive steel
b	25	35	10	98	735	×	Comparative steel
b1	8	5	11	96	740	×	Comparative steel
c	10	10	13	196	1029	×	Comparative steel
d	10	10	6	137	833	△	Comparative steel
e	15	40	22	216	1274	○	Inventive steel
e1	15	20	22	230	1400	○	Inventive steel
f	5	10	31	235	1666	○	Inventive steel
f1	5	30	29	205	1650	○	Inventive steel
g	1	15	25	274	1666	○	Inventive steel

\*1: Heat history in the temperature range from 1,000 to 1,300°C until hot-rolling

commences: temperature (°C) × time (min.)/10,000

\*2: Average cooling rate in the period of time from the commencement of the finish hot-rolling to the coiling after the completion of the finish hot-rolling: °C/sec.

Table 3

Steel	C	Si	Mn	P	S	Al	N	B	O	B/N	*1	Al/B	Ti	Nb
i	0.0021	0.02	0.52	0.01	0.007	0.012	0.0024	0.0023	0.0025	0.96	0.15	5.2	0.002	0.001
h	0.0022	0.018	0.52	0.009	0.01	0.012	0.002	0.0022	0.0032	1.1	0.02	5.5	0.025	0
j	0.0024	0.02	0.5	0.008	0.011	0.01	0.0017	0.002	0.0019	1.18	0.08	5	0.002	0.01
k	0.0018	0.021	0.47	0.008	0.009	0.009	0.0022	0.002	0.004	0.91	0.06	4.5	0.013	0.015

\*1: (N existing as AlN)/(N existing as BN)

Table 4

Steel	*1	*2	Workability (%)	Strength (N)	Fatigue strength (N)	Heat buckling	Judgment
h	10	10	31	225	1617	○	Inventive steel ◎
i	8	15	26	216	1274	△	Inventive steel ○
j	10	10	25	255	1274	△	Inventive steel ○
k	10	10	25	274	1176	△	Inventive steel △

\*1: Heat history in the temperature range from 1,000 to 1,300°C until hot-rolling

commences: temperature (°C) × time (min.)/10,000

\*2: Average cooling rate in the period of time from the commencement of the finish hot-

rolling to the coiling after the completion of the finish hot-rolling: °C/sec.

Table 5

Steel	C	Si	Mn	P	S	Al	N	B	O	B/N	*1	Al/B	*2
l	0.0015	0.203	0.2	0.005	0.008	0.009	0.0024	0.0033	0.002	1.38	0.05	2.7	0.02
m	0.0013	0.2	0.21	0.009	0.011	0.01	0.002	0.0018	0.0014	0.9	0.12	5.6	0.08
n	0.0023	0.252	0.08	0.015	0.011	0.012	0.0016	0.002	0.0046	1.25	0.06	6	0.19
o	0.0028	0.021	0.15	0.008	0.009	0.011	0.0027	0.0024	0.0051	0.89	0.08	4.6	0.13

\*1: (N existing as AlN)/(N existing as BN)

\*2: (S existing as Cu sulfides)/(S existing as Mn sulfides)

Table 6

Steel	*1	*2	Workability (%)	Strength (N)	Fatigue strength (N)	Heat buckling	Judgment
l	10	10	33	250	1750	○	◎ Inventive steel
m	15	10	27	240	1800	○	◎ Inventive steel
n	10	15	18	290	1400	△	△ Inventive steel
o	15	10	20	220	1200	△	△ Inventive steel

\*1: Heat history in the temperature range from 1,000 to 1,300°C until hot-rolling

commences: temperature (°C) × time (min.)/10,000

\*2: Average cooling rate in the period of time from the commencement of the finish hot-rolling to the coiling after the completion of the finish hot-rolling: °C/sec.



## Example 2

The workability of a weld was evaluated, as shown in Figure 1, by forming a quadrangular steel sheet into a cylindrical shape with seam welding, as in the case of manufacturing the can drum of a regular three-piece beverage can, expanding an opening by thrusting a conical die into the opening, and calculating the amount of deformation until cracking occurred at the opening end using the following expression;

$$\frac{\{(\text{Diameter at crack generation}) - (\text{Initial diameter})\}}{(\text{Initial diameter})} \quad (1).$$

The strength of a weld was evaluated, as shown in Figure 2, by welding two quadrangular steel sheets with spot welding at a welding current just lower than the current at which welding burrs occurred, and measuring the maximum load at a tensile test.

The fatigue strength of a weld was evaluated, as shown in Figure 3, by cutting out a strap 20 mm in width having a weld in the center from a welded cylindrical can drum formed as shown in Figure 6, subjecting the strap to a fatigue tensile test at one side oscillation, and measuring the maximum load at which it can withstand 10 million cycles.

Heat buckling was judged by whether or not heat buckling occurred when cold-rolled coils having identical thickness and width were passed through an identical annealing line at the temperature of the recrystallization temperature + 40°C, and the results were expressed by the marks, O: no occurrence, Δ: little occurrence and x: frequent occurrence.

The effects of the present invention were evaluated by synthetically judging the above-mentioned four evaluation items and expressed by the marks, ◎: excellent (invented steels), O: good (invented steels), Δ: good in some of the evaluation items (invented steels) and x: ordinary level (comparative steels).

## Concrete example 5

The steels having the chemical components shown in Table 7 were cast into slabs 250 mm in thickness, then hot-rolled sheets 2.2 mm in thickness were produced at the slab reheating temperature of 1,150°C and the coiling temperatures of 520 to 730°C, and then steel sheets 0.16 mm in thickness were produced through the processes of pickling, cold-rolling at the reduction ratio of 92%, annealing at 660 to 720°C for 1 min., and rolling at the reduction ratio of 10%, and the produced steel sheets were evaluated. The results are shown in Table 8.

As it is clear from Table 8, the steels produced within the ranges specified in the present invention show excellent properties in all the evaluation items such as the workability, the strength and the fatigue strength of the welds and the heat-buckling resistance.

Table 7

Steel	C	Si	Mn	P	S	Al	N	Solute N	Others
a	0.0012	0.230	0.96	0.011	0.011	0.008	0.0055	0.0050	
b	0.0150	0.014	0.61	0.008	0.018	0.041	0.0136	0.0033	
c	0.0244	0.003	0.21	0.009	0.013	0.012	0.0080	0.0066	Ti:0.0023
d	0.0268	0.010	0.23	0.008	0.016	0.015	0.0091	0.0081	Nb:0.0013
e	0.0386	0.008	0.20	0.014	0.016	0.020	0.0069	0.0040	B:0.0003, Ni:0.011
f	0.0235	0.013	0.18	0.016	0.012	0.013	0.0075	0.0052	Cr:0.035
g	0.0351	0.022	0.13	0.004	0.035	0.005	0.0077	0.0071	Sn:0.0015
h	0.0267	0.530	0.10	0.018	0.008	0.001	0.0013	0.0009	
i	0.0300	0.001	2.11	0.010	0.022	0.014	0.0092	0.0047	
j	0.0282	0.022	0.20	0.015	0.009	0.014	0.0070	0.0051	

Table 8

Steel	*1	*2	Workability (%)	Strength (N)	Fatigue strength (N)	Heat buckling	Judgment
a	10	20	20	305	1850	△	Inventive steel
b	25	40	20	293	1765	△	Inventive steel
c	10	35	28	293	1750	○	Inventive steel
c1	10	10	28	323	1840	○	Inventive steel
d	12	10	31	368	1910	○	Inventive steel
d1	30	40	27	333	1770	○	Inventive steel
e	8	10	26	321	1820	○	Inventive steel
e1	30	10	26	322	1770	○	Inventive steel
f	5	10	29	345	1865	○	Inventive steel
g	8	10	32	330	1795	○	Inventive steel
h	30	40	10	240	1550	△	Comparative steel
h1	10	10	12	238	1560	△	Comparative steel
i	8	10	16	290	1760	×	Comparative steel
j	8	10	15	224	1545	△	Comparative steel

\*1: Heat history in the temperature range from 1,000 to 1,300°C until hot-rolling

commences: temperature (°C) × time (min.)/10,000

\*2: Average cooling rate in the period of time from the commencement of the finish hot-rolling to the completion of the completion of the finish hot-rolling: °C/sec.

Concrete example 6

The steels having various amounts of O as shown in Table 9 were evaluated. The production conditions were the same as those of Example 1. The results are shown in Table 10.

As it is clear from Table 10, the steels produced within the preferable ranges show excellent properties in all the evaluation items such as the workability, the strength and the fatigue strength of the welds and the heat-buckling resistance.

Table 9

Steel	C	Si	Mn	P	S	Al	N	Solute N	O
k	0.0264	0.021	0.24	0.012	0.011	0.009	0.0094	0.0073	0.0005
l	0.0270	0.020	0.24	0.008	0.012	0.011	0.0077	0.0059	0.0032
m	0.0233	0.019	0.25	0.015	0.015	0.015	0.0132	0.0083	0.0062
n	0.0261	0.021	0.20	0.011	0.011	0.008	0.0080	0.0060	0.0096

Table 10

Steel	*1	*2	Workability (%)	Strength (N)	Fatigue strength (N)	Heat buckling	Judgment
k	20	20	25	288	1725	○	Inventive steel
l	2	10	33	309	1880	○	Inventive steel
m	8	5	30	357	1870	○	Inventive steel
n	25	10	21	361	1780	○	Inventive steel

\*1: Heat history in the temperature range from 1,000 to 1,300°C until hot-rolling commences: temperature (°C) × time (min.)/10,000

\*2: Average cooling rate in the period of time from the commencement of the finish hot-rolling to the completion after the completion of the finish hot-rolling: °C/sec.

## Concrete example 7

The steels having various amounts of Cu as shown in Table 11 were evaluated. The production conditions were the same as those of Example 1. The results are shown in  
5 Table 12.

As it is clear from Table 12, the steels produced within the preferable ranges show excellent properties in all the evaluation items such as the workability, the strength and the fatigue strength of the welds and the  
10 heat-buckling resistance.

Table 11

Steel	C	Si	Mn	P	S	Al	N	Solute N	Cu	*1
o	0.0345	0.022	0.08	0.009	0.015	0.008	0.0096	0.0065	0.010	0.03
p	0.0312	0.035	0.04	0.009	0.011	0.014	0.0069	0.0053	0.031	0.34
q	0.0336	0.052	0.20	0.010	0.011	0.016	0.0080	0.0062	0.045	0.12
r	0.0367	0.022	0.22	0.008	0.013	0.012	0.0085	0.0063	0.061	0.10

\*1: (S existing as Cu sulfides)/(S existing as Mn sulfides)

Table 12

Steel	*1	*2	Workability (%)	Strength (N)	Fatigue strength (N)	Heat buckling	Judgment
o	10	10	30	320	1865	○	Inventive steel
p	10	10	27	285	1750	○	Inventive steel
q	20	20	30	310	1800	○	Inventive steel
r	20	20	25	290	1770	○	Inventive steel

\*1: Heat history in the temperature range from 1,000 to 1,300°C until hot-rolling

commences: temperature (°C) × time (min.)/10,000

\*2: Average cooling rate in the period of time from the commencement of the finish hot-rolling to the coiling after the completion of the finish hot-rolling: °C/sec.



As explained above, by the present invention, it is possible to reduce the bad formability caused by welding and the fracture during the usage of a can having a weld. Further, since a steel according to the present invention has excellent properties even at an annealing temperature lower than an ordinary annealing temperature, the occurrence of heat buckling can be avoided and an ultra-thin material for a container can be produced with a high efficiency.

CLAIMS

1. A steel sheet for a container, excellent in formability and fatigue property at a weld, characterized by: containing, in mass,  
5 C: 0.0050% or less,  
N: 0.0060% or less, and  
B so that the ratio B/N may be within the range from 0.40 to 2.00; and  
having AlN and BN in the steel satisfy the expression,  
10  $(N \text{ existing as AlN}) / (N \text{ existing as BN}) \leq 0.40$ .
2. A steel sheet for a container, excellent in formability and fatigue property at a weld, according to claim 1, characterized by: further containing, in mass,  
Al: 0.040% or less; and  
15 the ratio Al/B being 30 or less.
3. A steel sheet for a container, excellent in formability and fatigue property at a weld, according to claim 1 or 2, characterized by further containing, in mass,  
20 O: 0.0010 to 0.0070%.
4. A steel sheet for a container, excellent in formability and fatigue property at a weld, according to any one of claims 1 to 3, characterized by further containing, in mass,  
25 Si: 0.015 to 2.00%,  
Mn: 0.05 to 2.00%, and  
P: 0.005 to 0.080%.
5. A steel sheet for a container, excellent in formability and fatigue property at a weld, according to any one of claims 1 to 4, characterized by further containing, in mass,  
30 Ti: 0.010% or less and  
Nb: 0.010% or less.
6. A steel sheet for a container according to any one of claims 1 to 5, characterized in that the sulfides contained in the steel satisfy the expression;  
35

(S existing as Cu sulfides)/(S existing as Mn sulfides)  $\leq$  0.10.

7. A method of producing a steel sheet for a container, excellent in formability and fatigue property at a weld, characterized by controlling the reheating temperature of a slab to 1,100°C or higher in hot-rolling when the steel sheet for a container is produced in the ordinary production processes using a steel containing the components according to any one of claims 1 to 6.

8. A method of producing a steel sheet for a container, excellent in formability and fatigue property at a weld, characterized by controlling the coiling temperature to 730°C or lower in hot-rolling when the steel sheet for a container is produced in the ordinary production processes using a steel containing the components according to any one of claims 1 to 6.

9. A method of producing a steel sheet for a container, excellent in formability and fatigue property at a weld, characterized by controlling the annealing temperature after cold-rolling to 700°C or lower when the steel sheet for a container is produced in the ordinary production processes using a steel containing the components according to any one of claims 1 to 6.

10. A steel sheet for a container, excellent in formability and fatigue property at a weld, characterized by: containing, in mass,  
C: 0.0005 to 0.040%,  
Si: 0.002 to 0.50%,  
Mn: 0.03 to 2.00%,  
P: 0.002 to 0.080%,  
S: 0.0100 to 0.0600%,  
Al: 0.0010 to 0.0700%, and  
N: 0.0020 to 0.0300%;  
the content of N dissolved in the steel sheet being 20 to 300 ppm; and  
the balance consisting of Fe and unavoidable impurities.

11. A steel sheet for a container, excellent in

formability and fatigue property at a weld, according to claim 10, characterized by further containing, in mass, one or more of,

Nb: 0.0005 to 0.0050%,

5 Ti: 0.0005 to 0.0050%, and

B: 0.0010% or less.

12. A steel sheet for a container, excellent in formability and fatigue property at a weld, according to claim 10 or 11, characterized by further containing, in mass,

10 O: 0.0015 to 0.0090%.

13. A steel sheet for a container, excellent in formability and fatigue property at a weld, according to any one of claims 10 to 12, characterized by further containing, in mass, one or more of,

15 Cu: 0.0005 to 0.050%,

Ni: 0.0005 to 0.100%, and

Cr: 0.0005 to 0.100%.

14. A steel sheet for a container, excellent in formability and fatigue property at a weld, according to any one of claims 10 to 13, characterized by further containing, in mass,

20 Sn: 0.0002 to 0.0050%.

15. A steel sheet for a container, excellent in formability and fatigue property at a weld, according to any one of claims 10 to 14, characterized in that the sulfides contained in the steel satisfy the expression, (S existing as Cu sulfides)/(S existing as Mn sulfides) < 0.30.

16. A method of producing a steel sheet for a container, excellent in formability and fatigue property at a weld, according to any one of claims 10 to 15, characterized in that the steel sheet is subjected to a secondary cold-rolling under the reduction ratio of 20% or less after the processes of continuous casting of molten steel, hot-rolling, pickling, cold-rolling and annealing.

30

35

17. A method of producing a steel sheet for a container, excellent in formability and fatigue property at a weld, according to any one of claims 1 to 16, characterized by commencing hot-rolling under the condition that the heat history in the temperature range from 1,000 to 1,300°C after producing a slab by continuously casting molten steel and before commencing the hot-rolling satisfies the expression,
- temperature (°C) x time (min.)  $\leq$  200,000.
18. A method of producing a steel sheet for a container, excellent in formability and fatigue property at a weld, according to any one of claims 1 to 17, characterized by hot-rolling the steel sheet by controlling the average cooling rate in the period of time from the commencement of the finish hot-rolling to the coiling after the completion of the finish hot-rolling to 30°C/sec. or less.

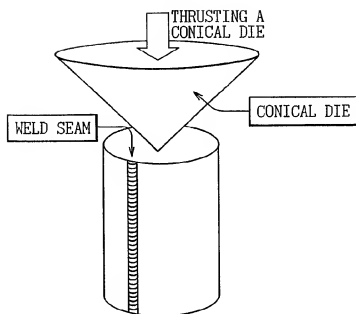
$\frac{1}{2}$   
Fig.1

Fig.2

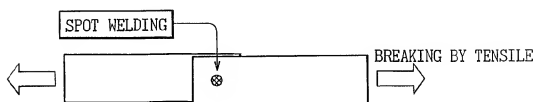
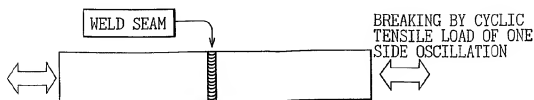


Fig.3



$\frac{2}{2}$ 

Fig.4

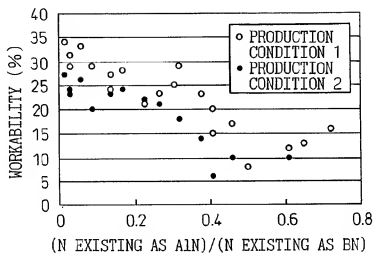
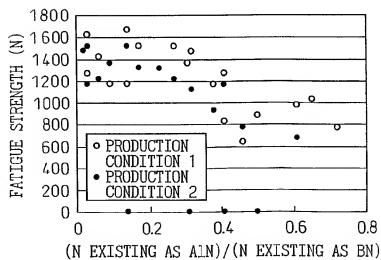


Fig.5



## INTERNATIONAL SEARCH REPORT

International Application No.

PCT/JP 02/10387

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C22C36/06

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C22C C21D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EP0-Internal, PAJ, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category \* Citation of document, with indication, where appropriate, of the relevant passages

Relevant to claim No.

X	EP 0 672 758 A (KAWASAKI STEEL CO) 20 September 1995 (1995-09-20) page 6, line 47-50 page 7, line 2 page 7, line 16; table 1	1,5,7,8, 17,18
A	---	2,4,9, 10,16
X	EP 0 769 565 A (NIPPON STEEL CORP) 23 April 1997 (1997-04-23) page 4, line 40,41 abstract; table 1	1,4,5, 7-9,17
A	---	10,16,18
	--- --	

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

## \* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document relating to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"A" document member of the same patent family

Date of the actual completion of the international search

7 February 2003

Date of mailing of the international search report

25.02.03

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-73) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-73) 340-2018

Authorized officer

LINDA NELIN/JA A



## INTERNATIONAL SEARCH REPORT

International Application No

PCT/JP 02/10387

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 01, 30 January 1998 (1998-01-30) & JP 09 227947 A (NKK CORP), 2 September 1997 (1997-09-02) abstract	1,10
A	---	7-9, 16-18
X	US 6 129 992 A (ITAMI ATSUSHI ET AL) 10 October 2000 (2000-10-10) column 8, line 33-39; tables 1,2 -----	1,2,4,6, 9

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/JP 02/10387

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 0672758	A	20-09-1995	CN 1118814 A ,B	20-03-1996
			DE 69518451 D1	28-09-2000
			DE 69518451 T2	04-01-2001
			EP 0672758 A1	20-09-1995
			JP 7278678 A	24-10-1995
			KR 221349 B1	15-09-1999
			US 5587027 A	24-12-1996
-----				
EP 0769565	A	23-04-1997	JP 8283908 A	29-10-1996
			EP 0769565 A1	23-04-1997
			US 5855696 A	05-01-1999
			CN 1152340 A	18-06-1997
			WO 9630555 A1	03-10-1996
			JP 8325634 A	10-12-1996
-----				
JP 09227947	A	02-09-1997	NONE	
-----				
US 6129992	A	10-10-2000	JP 2002012956 A	15-01-2002
			JP 2000290759 A	17-10-2000
			CN 1361304 A	31-07-2002
			CN 1361305 A	31-07-2002
			CN 1249786 T	05-04-2000
			GB 2336601 A ,B	27-10-1999
			WO 9923268 A1	14-05-1999
-----				